MEMORANDUM

To: ESHMC
Fr: B. Contor
Date: 23 January 2008

Re: Recharge on non-irrigated lands

As a follow-up to the 8 January 2008 ESHMC discussion on recharge on non-irrigated lands, this memo discusses three different topics related to non-irrigated lands recharge:

1. Incorporating calculation parameters inside PEST.
2. Allen-Robinson daily soil moisture balance calculations vs. ESPAM1.1 representation.
3. Spatial interpolation of weather-station data to the entire ESPA.

Incorporating calculation parameters inside PEST

Currently, the non-irrigated recharge calculations are performed on the basis of *GIS Polygons.* This is done offline, before the non-irrigated recharge rasters are presented to the GIS part of the recharge tool. The ability for PEST to adjust non-irrigated recharge is contained in multipliers which scale the per-cell values of non-irrigated recharge that are presented to the FORTRAN part of the recharge tool. Four different spatial regions can be independently scaled, and additional regions can be accommodated with minor modification to the recharge tool.

The FORTRAN tool as currently designed can only perform calculations on a per-cell basis. Figure 1 shows that some of the "other" polygons (wetlands, cities, and dry farms) are small relative to the size of individual model cells.

An option discussed at the ESHMC meeting was to allow PEST to not only scale the results of the non-irrigated recharge calculation, but to actually adjust the parameters of the algorithm. This could be done by a simple stand-alone pre-processor to the FORTRAN part of the recharge tool, or by modifying the tool itself. The former has the advantages of being easier to adopt and easily adaptable to different or modified algorithms. The latter option perhaps has an advantage of quicker run times. Neither would be able to accommodate separate calculation of polygons smaller than a single model cell. Allowing a PEST-touchable calculation on a per-polygon basis would require either a sophisticated stand-alone pre-processor or an essentially ground-up rebuild of the entire recharge tool (GIS and FORTRAN parts).

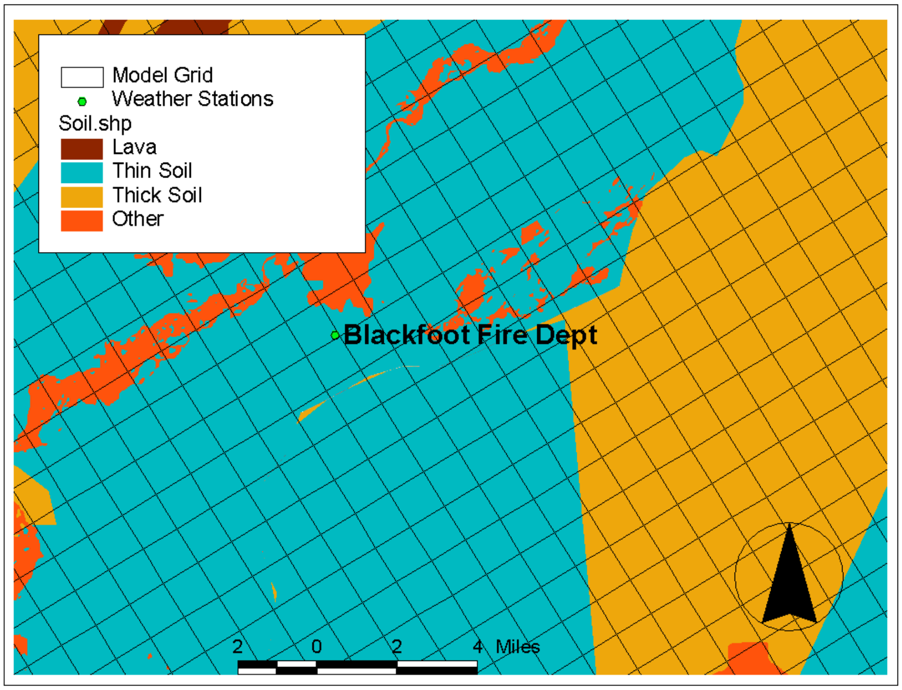

Figure 1. Illustration of the typical size of "other" category polygons relative to model grid cells.

Figure 2 illustrates an issue that arose in the ESPAM1.1 calibration related to the size of polygons and the operation of the recharge tool. The central model cell in the figure is approximately half irrigated land on thick soils and half wetlands. The pre-processing of non-irrigated recharge rasters calculated a very small positive recharge depth on the thick-soil portion of this cell, and a large net evapotranspiration depth (aquifer extraction) on the wetland portion of the cell. The GIS part of the tool passed to FORTRAN the *average* net recharge in the entire cell, which was an extraction depth equal to about half the net extraction depth of the wetlands portion of the cell.

The GIS tool also passed to FORTRAN the irrigated acreage within the cell, total cell area, the irrigated-lands evapotranspiration depth, and the various entity, diversions, returns, offsite pumping and canal-leakage data needed to calculate the net impact of irrigation. After calculating the net impact of irrigation, FORTRAN subtracted the irrigated acreage from the total cell area and obtained non-irrigated acreage in the cell. To the *non-irrigated portion* of the cell, it applied the *whole-cell-average* non-irrigated recharge depth. The result was that cells such as the one illustrated showed about half of the net extraction that the data indicated they should have. This was handled in ESPAM1.1 with manually-calculated adjustments applied to the "W" (wetlands) class of points in the "fixed-point" input data.

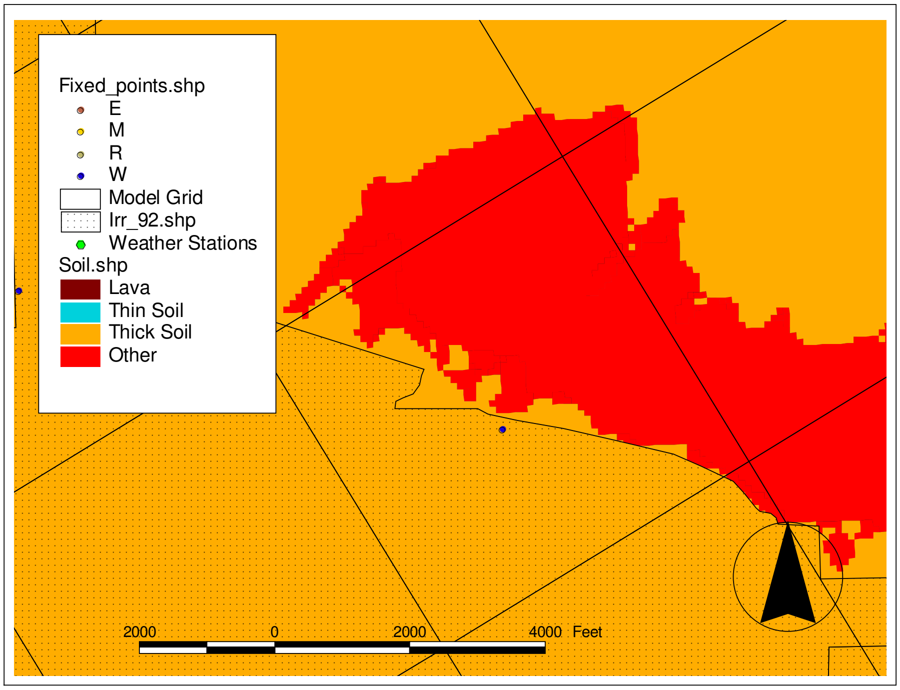

Figure 2. Wetlands and irrigation in the same model cell.

Whether we use the current capability of letting PEST scale non-irrigated recharge or decide to allow PEST to adjust the non-irrigated-recharge parameters, we could modify our procedures to address both the small-polygon and wetlands-depth issues. The modification would simply be to directly apply the impact of the minor classes (cities, wetlands, etc.) in the fixed-point pumping data and use the non-irrigated recharge rasters to represent only the recharge from precipitation on non-irrigated lands. The procedure could be changed without any modification to the GIS or FORTRAN parts of the tool.

Allen-Robison Daily Soil Water Balance Calculations of Recharge

IWRRI agreed to do some comparisons with the Allen-Robinson (U of I, Kimberly) daily soil water balance calculations for the Snake Plain. Figure 3 illustrates the precipitation/recharge relationship used in ESPAM1.1. Its key feature in this context is that there is a fixed relationship between precipitation and recharge. Figures 4 through 6 show relationships between monthly precipitation and monthly recharge from the Allen-Robison data for the Aberdeen Idaho AGRIMET station. Depending on the nature of the monthly precipitation (a few high-intensity events or many smaller events), antecedent conditions and time of year, the Allen-Robison data show that recharge associated with a given precipitation depth can vary markedly. This better matches our conceptual understanding of the physical processes.

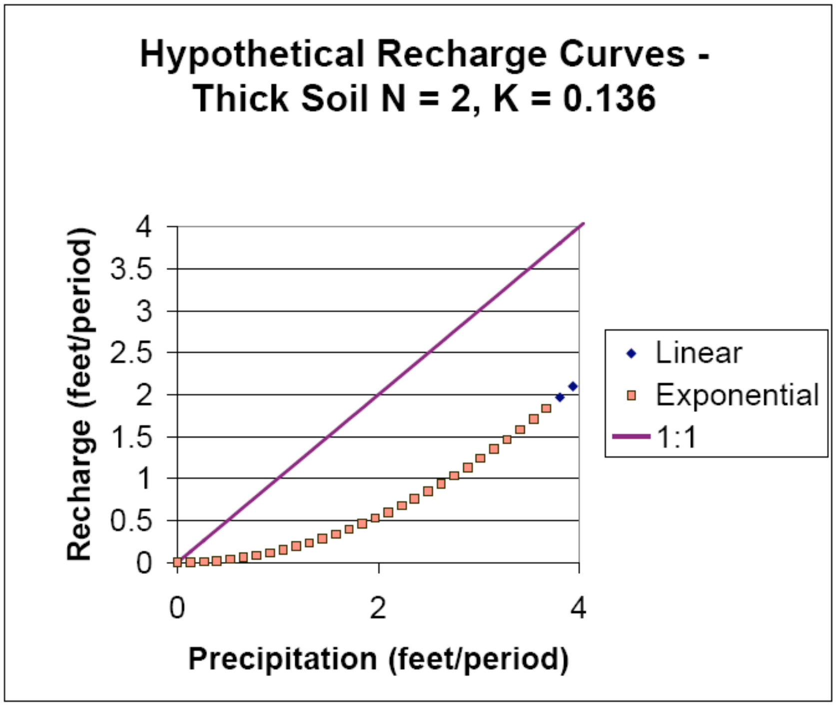

Figure 3. ESPAM1.1 precipitation/recharge relationship (this is Figure 7 in ESPAM1.1 design document DDW-003).

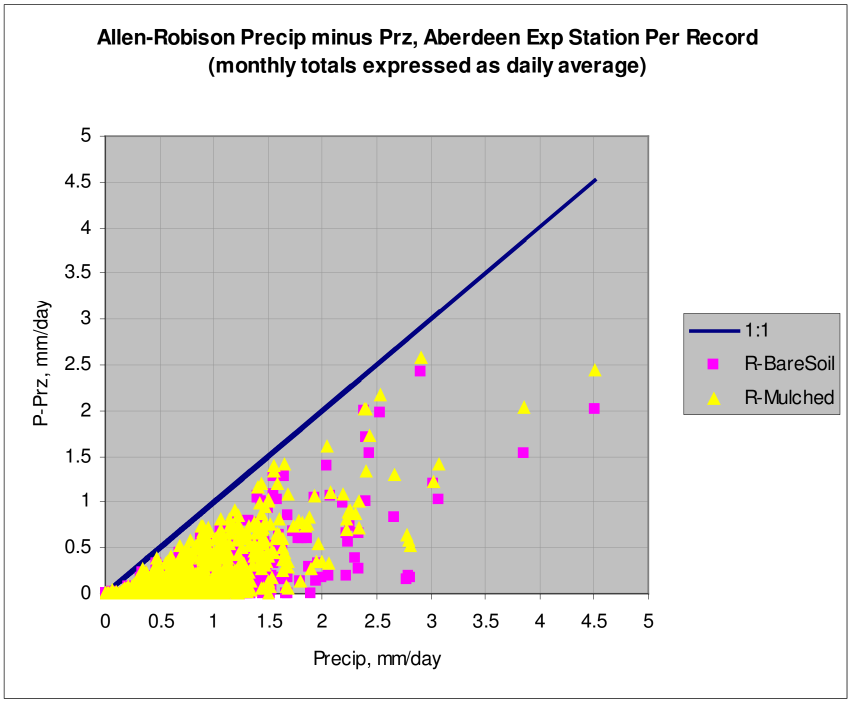

Figure 4. Allen-Robison data for bare soil and mulched soil.

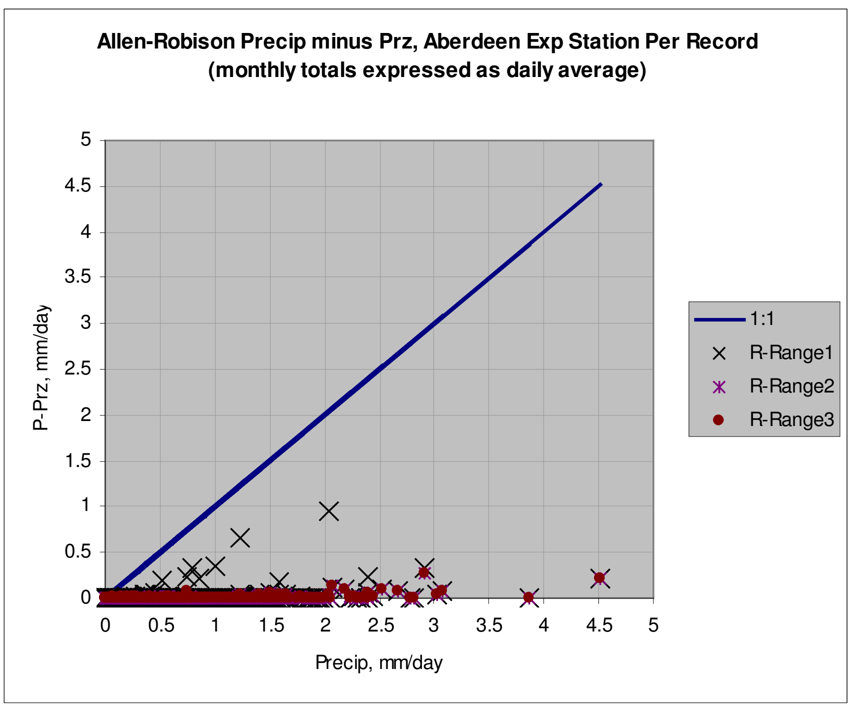

Figure 5. Allen-Robison calculations for range grass.

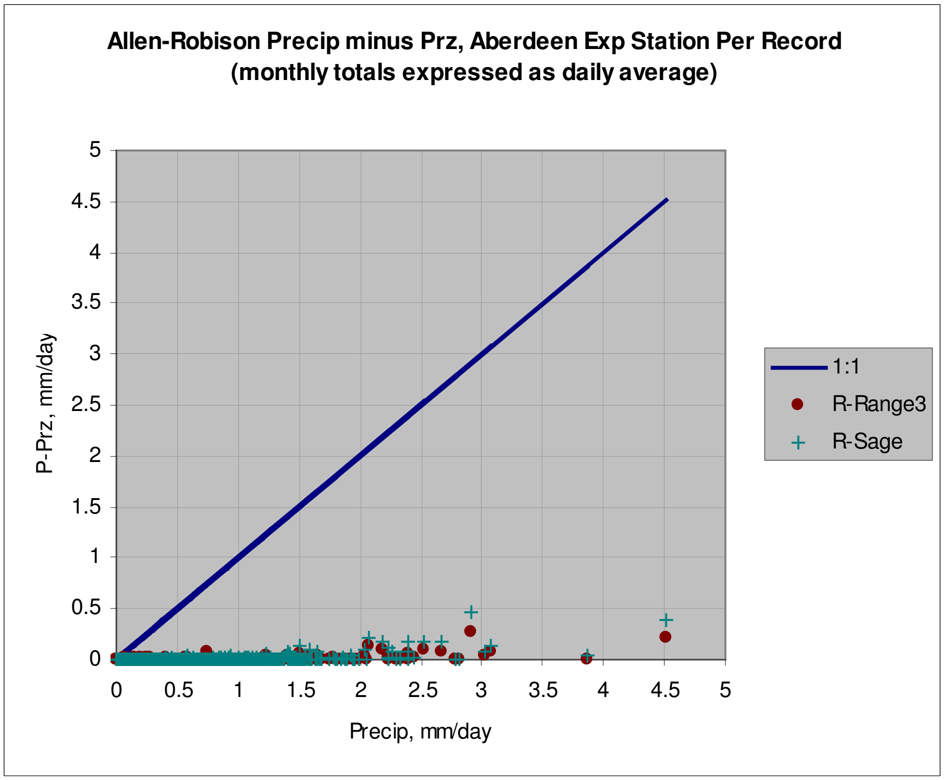

Figure 6. Allen-Robison calculations for one type of range grass and for sagebrush cover.

The time series of recharge for the three different ESPAM1.1 general soil types is illustrated in Figure 7. Figures 8, 9 and 10 compare ESPAM1.1 calculations to different Allen-Robison calculations. National Weather Service (NWS) stations' data starts prior to 1980, and the AGRIMET stations' period of record starts in the late 1980s or early 1990s (depending on station). With the exception of the Kilgore station (whose record ends in 1977), Allen-Robison estimates are available for all stations through December 2005.

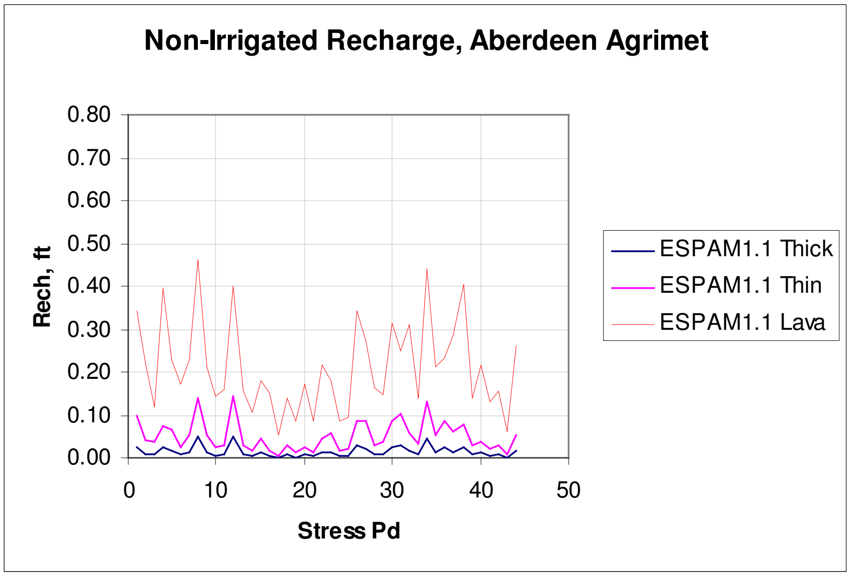

Figure 7. ESPAM1.1 recharge, Aberdeen, six-month periods.

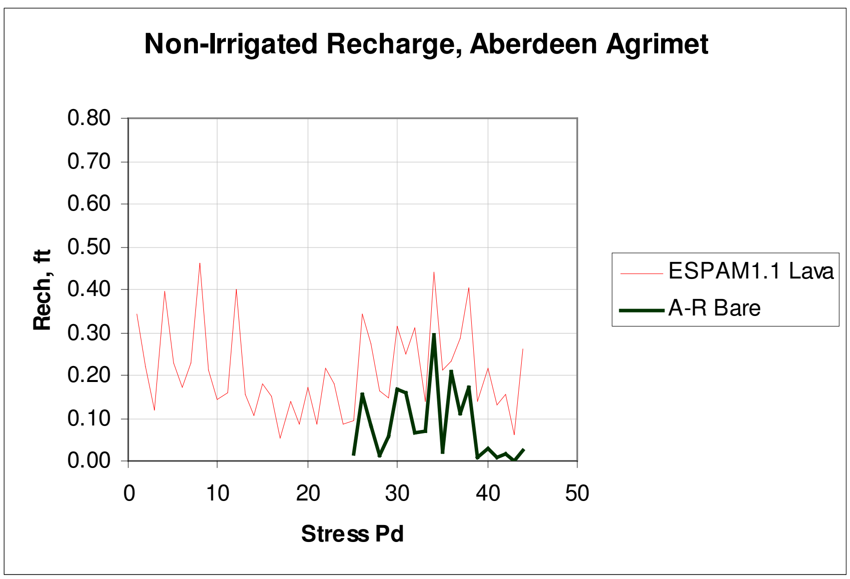

Figure 8. ESPAM1.1 lava-rock recharge and Allen-Robison bare soil recharge, six-month periods.

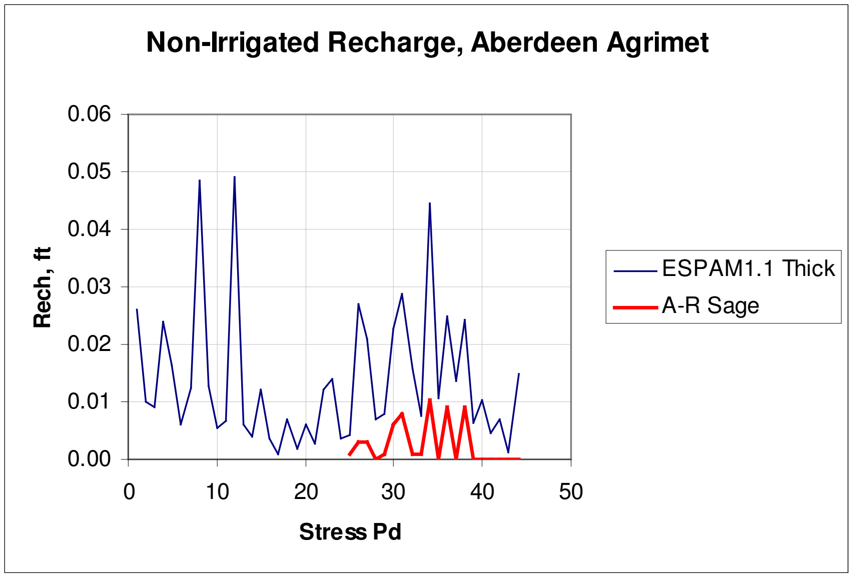

Figure 9. ESPAM1.1 thick-soil recharge and Allen-Robison Sage Brush recharge, six month periods.

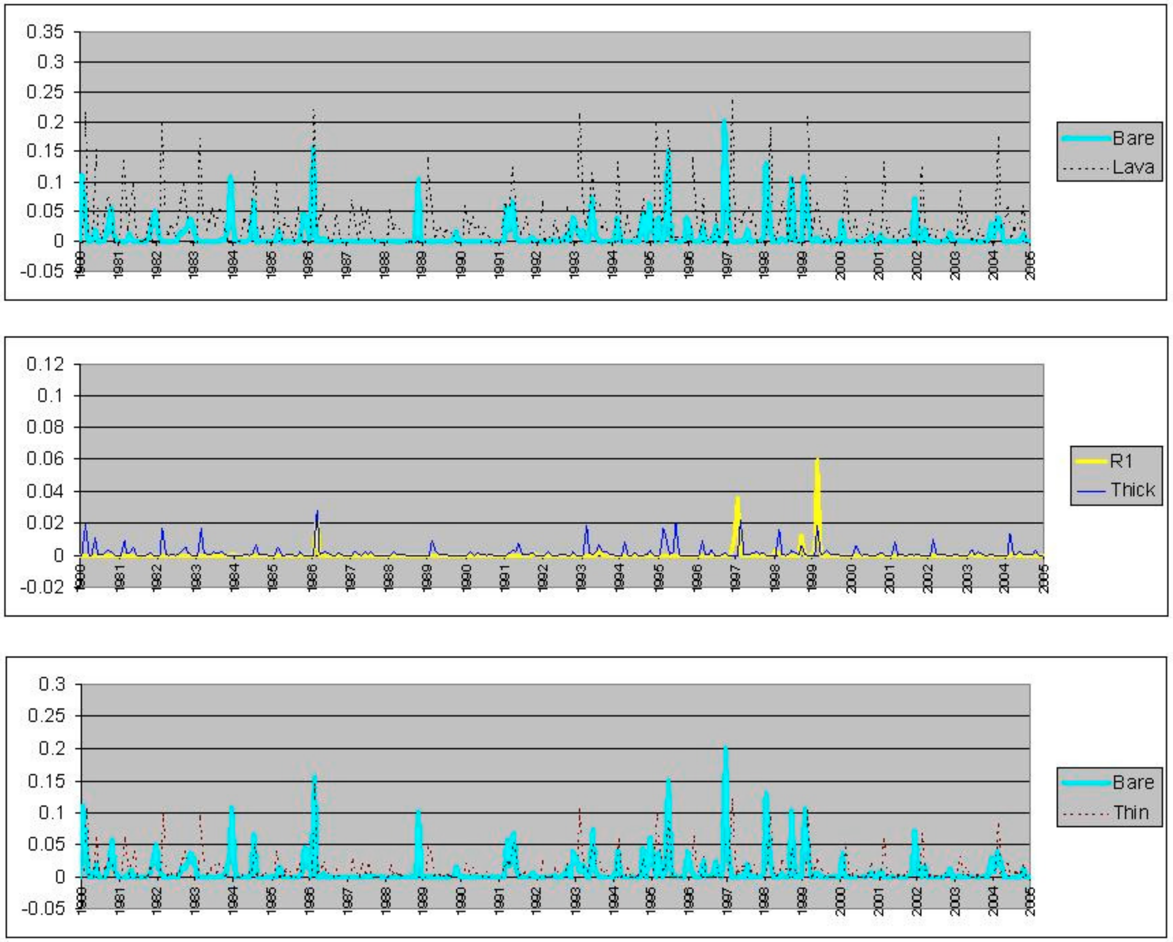

Figure 10. ESPAM1.1 and Allen-Robison monthly recharge, Aberdeen NWS weather station, one month periods.

Spatial Interpolation of Weather-station Data to the Entire ESPA

Another important consideration is spatial interpolation. The PRISM data are interpolated spatially using a complex algorithm that considers slope, elevation and aspect. However, the temporal resolution of PRISM is one month. If a daily moisture balance calculation is used, data must be spatially interpolated from the weather station locations shown in Figure 11.

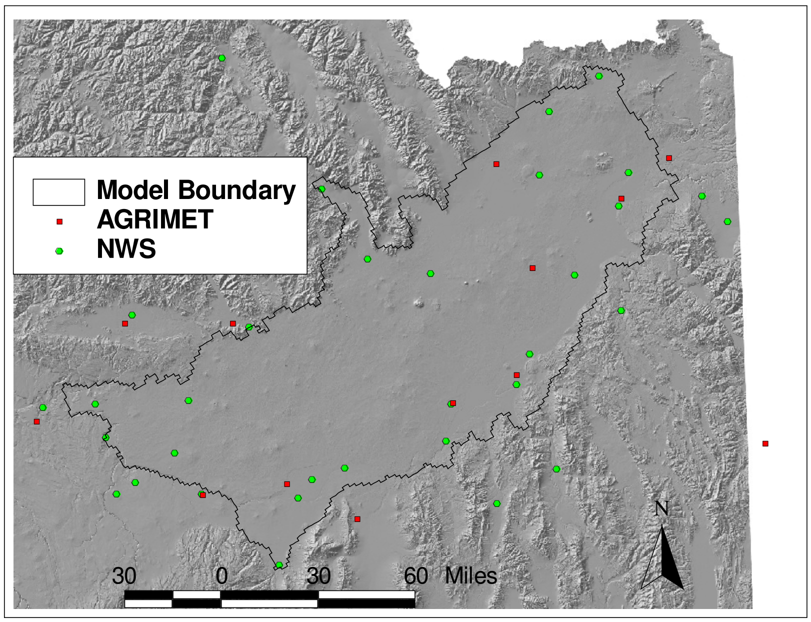

Figure 11. Weather station locations.

To consider the impacts of interpolation without being confounded by effects of different non-irrigated recharge calculation methods, point values of the PRISM data were extracted for each weather station and interpolated. Figures 12 through 16 show the spatial distribution of precipitation using various methods. Kriging is not included in the comparison due to software limitations of the computer used for this investigation. However, there are few enough data points that kriging is probably not appropriate.

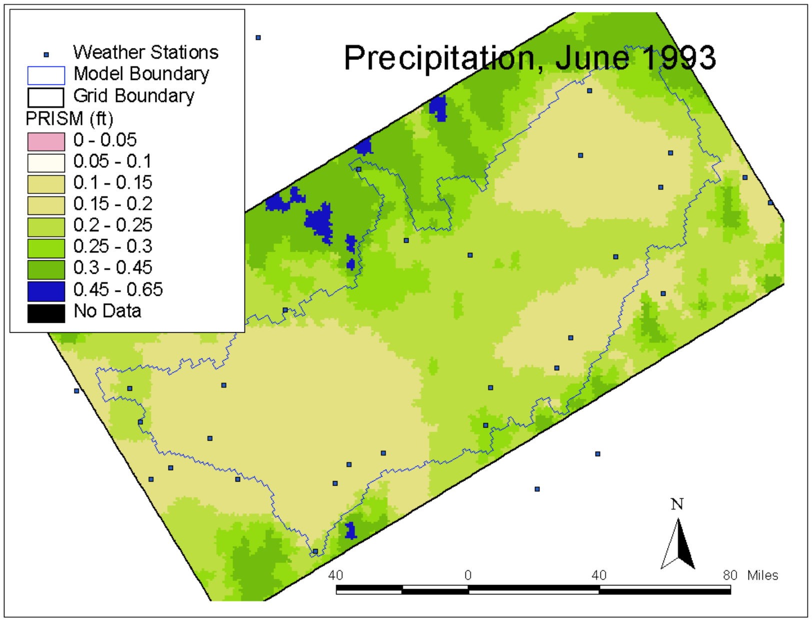

Figure 12. Spatial interpolation of PRISM precipitation using PRISM algorithm.

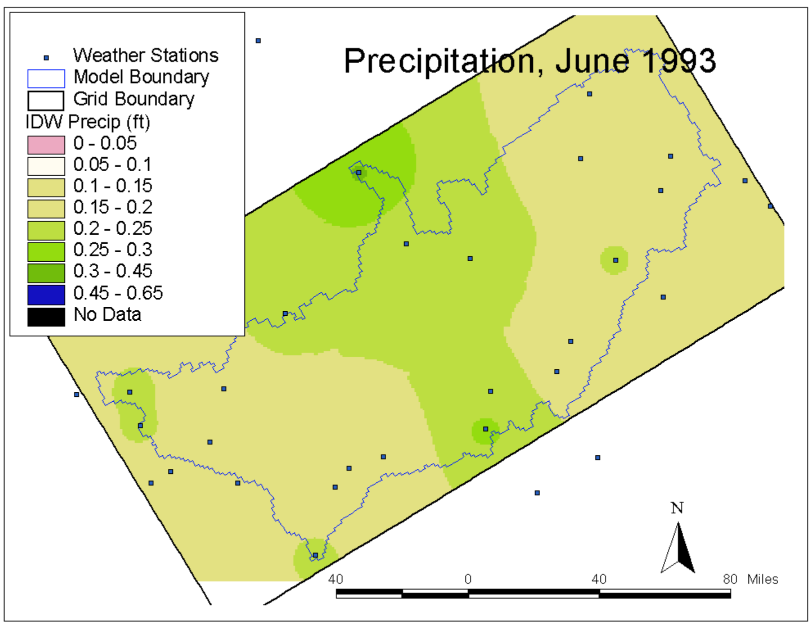

Figure 13. PRISM point values interpolated using Inverse Distance Weighting.

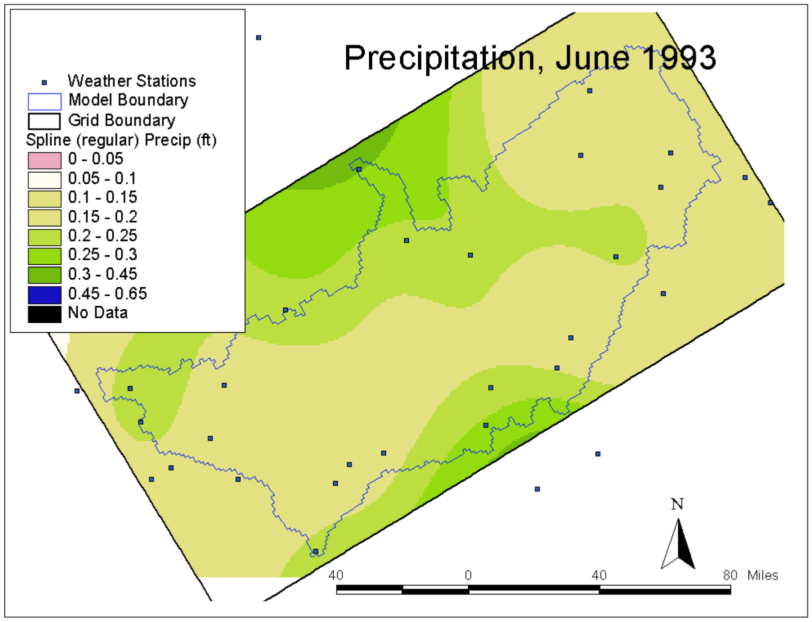

Figure 14. PRISM point values interpolated using Regularized Spline interpolation.

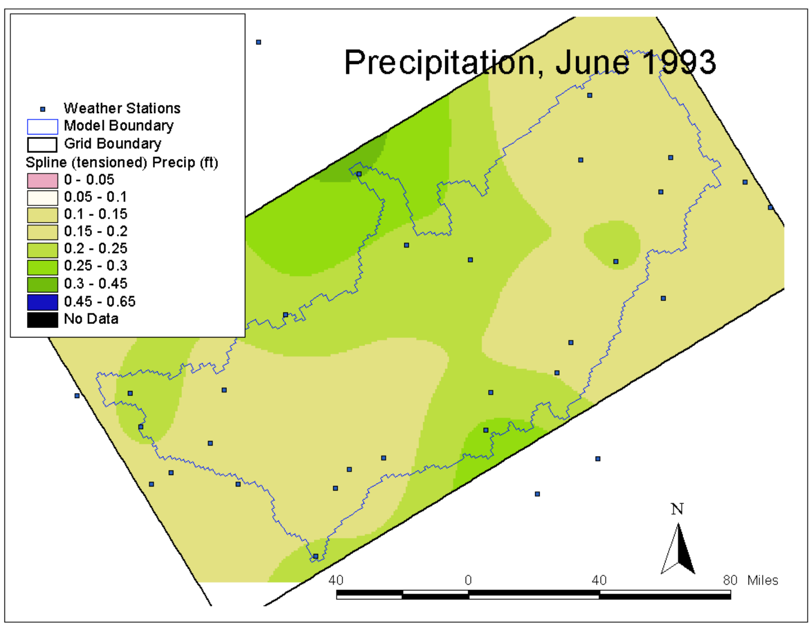

Figure 15. PRISM point values interpolated using Tensioned Spline interpolation.

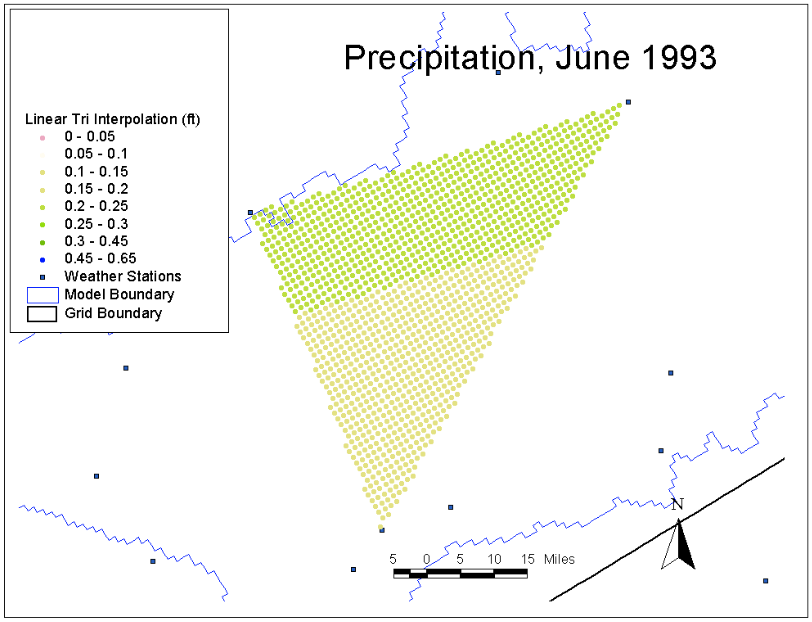

Figure 16. Linear triangular interpolation, sample area.[1]

Visually, all the interpolations seem similar within the plain; differences are concentrated in the mountains outside the study area. Figures 17 through 20 focus on the central area of the plain where weather stations are sparse. This is an area important to non-irrigated recharge because it is an area of higher precipitation and more permeable soils. Each figure gives the difference in feet between one of the GIS interpolations and the PRISM interpolation. For context, the differences range within approximately plus or minus 25% of the PRISM precipitation depth. Table 1 summarizes the differences within this area.

[1] For test purposes, this interpolation was manually constructed. With some setup work, a small utility program can be made to calculate the interpolation between all weather stations.

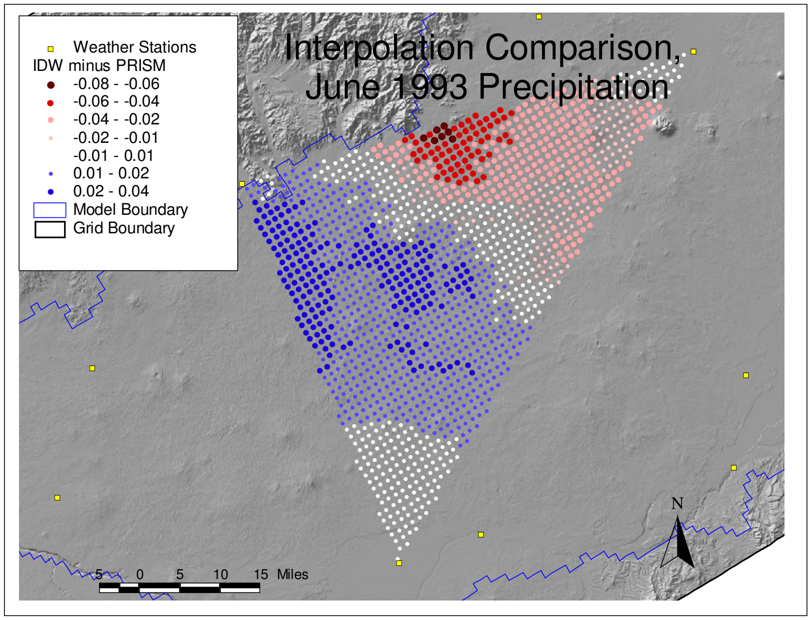

Figure 17. Inverse Distance Weighting interpolation minus PRISM interpolation.

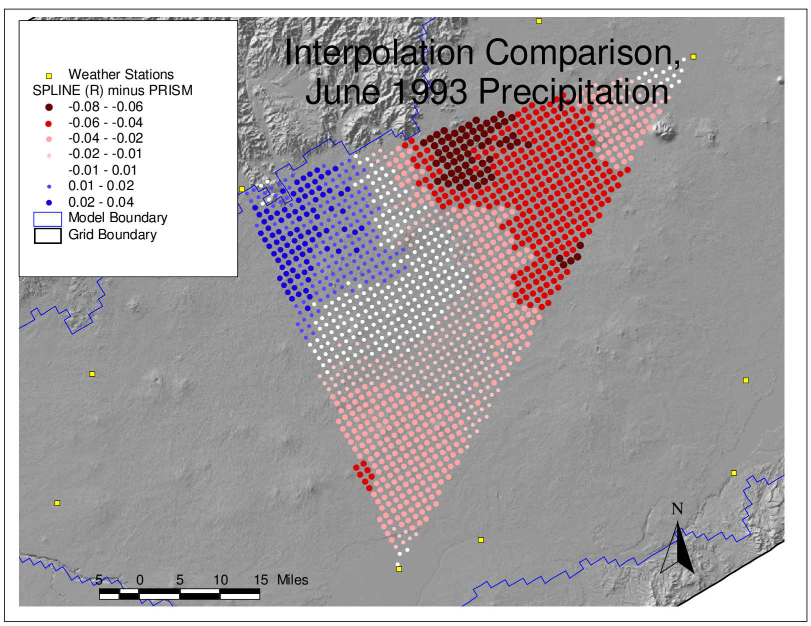

Figure 18. Regularized Spline interpolation minus PRISM interpolation.

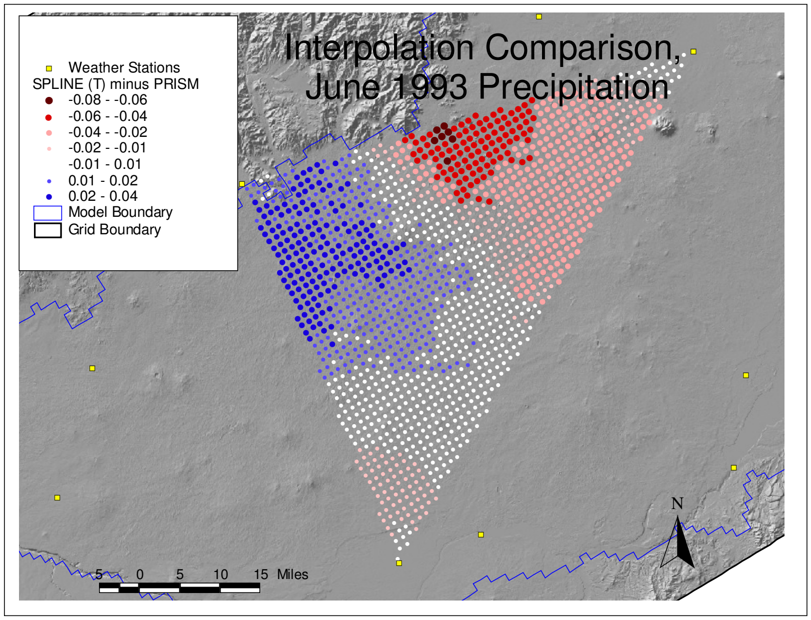

Figure 19. Tensioned Spline interpolation minus PRISM interpolation.

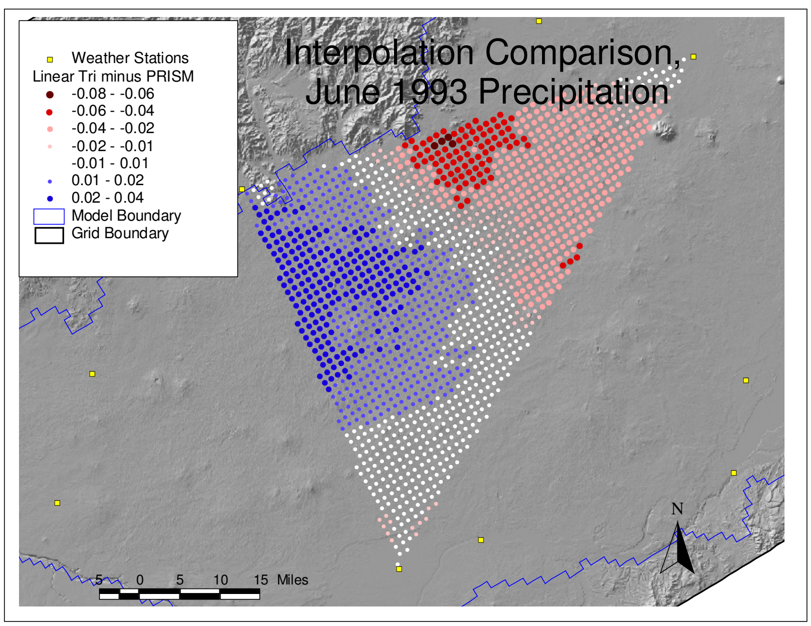

Figure 20. Linear Triangular interpolation minus PRISM interpolation.

Table 1
Summary of differences between GIS interpolations and
PRISM interpolations within the triangle area.
PRISM precipitation ranges from 0.14 to 0.29 feet, with mean 0.20 ft.

Statistic	IDW	Spline-Regularized	Spline-Tensioned	Linear Triangle
Mean Difference (ft)	-0.0010	-0.0205	-0.0051	-0.0031
Max Difference (ft)	0.0356	0.0306	0.0361	0.0404
Min Difference (ft)	-0.0629	-0.0759	-0.0650	-0.0621

Discussion and Recommendations

Incorporating calculation parameters inside PEST

1. Using the "fixed point" capability of the recharge tool seems more straightforward than the method used in ESPAM1.1 where wetlands appeared in the non-irrigated recharge calculations but required adjustment points in the "fixed point" data.
2. For many of the stations, the Allen-Robison data include estimates of wetlands ET that could be used regardless of the method chosen for recharge on dryland areas.
3. If we decide to allow PEST to adjust calculation parameters, doing this in a stand-alone utility allows greater flexibility in changing algorithms or approaches.

Allen-Robison daily soil moisture calculations vs. ESPAM1.1 calculation

1. With two types of bare soil, sagebrush and three types of rangeland grass estimates, the Allen-Robison data provide a broad range of recharge estimates. Note, however, that some stations have fewer options for non-irrigated land cover type.
2. Allen-Robison estimates have generally similar temporal patterns to the ESPAM1.1 estimates.
3. The highest-recharge Allen-Robison estimate is lower than the ESPAM1.1 lava-rock estimate. As part of ESPAM1.1 we attempted a water-budget assessment, which suggested that the ESPAM1.1 may have been low.
4. The Allen-Robison data only go through December 2005. If we decide to use these estimates, we have three options:
    a) Request Allen and Robison to extend their estimates through the calibration period.

b) Shorten the calibration period to match the period of the Allen-Robison estimates.
c) Use a correlation with precipitation or the ESPAM1.1 method to extend non-irrigated recharge estimates from January 2006 through the end of the calibration period.

Interpolation

1. Relative to PRISM, the maximum and minimum departures of the other interpolation methods are similar.
2. The average departures of Inverse Distance Weighting, Spline (Tensioned) and Linear Triangular interpolations are similar. Spline (Regularized) has a larger average departure.
3. Because of the number of months and sites involved, using standard GIS functions to do Inverse Distance Weighting or Spline would be quite time consuming.
4. The Linear Triangular interpolation could be done programmatically with a small stand-alone utility. It would take some time to write, but once written it would process the entire calibration-period data set in a matter of minutes.

Recommendations

1. Independently of our choice for non-irrigated recharge on non-cultivated dry lands, I propose using the "fixed point" capability of the Recharge Tool to represent minor uses.
2. I propose using the Allen-Robison estimates for wetland consumptive use, and ESPAM1.1 estimates for other minor uses.
3. In ESPAM1.1 we treated dry farms separately from adjacent uncultivated lands. For ESPAM2.0 I propose treating dry farms like any other non-irrigated lands of similar soil class. This is for convenience rather than any technical reason.
4. The utility of adjusting *parameters* of the non-irrigated recharge calculation seems only slightly (if at all) better than the utility offered by the current capability to *scale* non-irrigated recharge estimates (see summary memo of 8 January 2008 ESHMC meeting). Further, we are now contemplating a completely different approach, and may wish to consider still others in the future. Since the current scaling capability would work with any approach, I propose that we keep the current method, making a slight adjustment to allow nine zones (rather than the current four) for independent scaling by PEST. The zones I propose are the three general soil classes used in ESPAM1.1, divided into "north east," "central" and "south west" regions.
5. Because the temporal pattern of the Allen-Robison estimates is similar to the ESPAM1.1 values and because the Allen-Robison estimates extend

only through December 2005, I propose using the ESPAM1.1 method, applied to PRISM precipitation data.

6. If we do adopt the Allen-Robison estimates (or other estimates based on daily calculations), I propose using a linear triangular interpolation method for processing efficiency.